Population Diversity Control in Genetic Algorithm Method using the Discrete Wavelet Transform and the k-means clustering

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Abstract — Despite the computational advantages of the Genetic Algorithm technique, the method has some difficulties such as to define the size of the population and to preserve the diversity of this population. The simplest way to overcome this difficult is using large populations, but it may demand too much processing time for a good solution is found. This work proposes to use the discrete wavelet transform to explore possible correlations between individuals in a population of the Genetic Algorithm in order to eliminate redundancies between the individuals and ultimately reduce the number of objective functions evaluations necessary for convergence.

I. INTRODUCTION

Due to difficulties in obtaining exact solutions of optimization problems of practical importance in the science and engineering, metaheuristic techniques have been highlighted as promising approaches in many situations. Although not guarantee the optimality of their solutions, these methods provide acceptable solutions, even for complex problems. The ease of programming and the computational efficiency of these numerical techniques are its main advantages over the basic heuristic methods and deterministic optimization methods.

However, despite the computational advantages of the technique, the methods based on metaheuristics have some difficulties such as to define the size of the population and to preserve the diversity of this population. According to the literature [1], a small population can cause premature convergence of the algorithm which is an important issue in applying genetic algorithms to solve problems and it is generally caused by the lack of diversity of the population. Then again, a very large population may demand too much processing time for a good solution is found.

On the other hand, when it is applied in a data set the wavelets functions create a sparse approximation of the data by eliminating redundancies between the data values [2]. Therefore, the wavelets can be applied in order to select appropriate individuals from a population in metaheuristic methods, as is done in this work. The idea is to use the discrete wavelet transform to explore possible correlations between individuals in a population of the Genetic Algorithm (GA) in order to eliminate redundancies between the individuals and ultimately reduce the number of objective functions evaluations necessary for convergence. Due to the local action, the population is clustering using the k-means algorithm before the application of the discrete wavelet transform (DWT). The method was applied to unrestricted optimization problems involving test functions with several local minimum and compared with the results of the traditional GA.

II. THE GENETIC ALGORITHM METHOD

Genetic Algorithms are a family of iterative optimization procedures inspired by evolutionary principles. Instead of working with a single solution per iteration, a GA works with a number of potential solutions known as population, which is usually chosen stochastically in the initialization [3]. These potential solutions are encoded as a string coding of fixed length called a chromosome. Therefore for every iteration (also called generation) an evaluation of these chromosomes is carried out using a fitness function to allocate a fitness value for each solution. The fitness value should represent the goodness of a solution, which is typically defined with respect to the current population, and it is used to rank the population members in order to provide a kind of probability threshold for reproduction operation. If for example the GA optimization is maximizing some function the member with relatively higher fitness value should have a higher probability of reproduction. Then, after defining a probability threshold, the population is updated using operations of selection, crossover and mutation and the process is repeated until a termination criterion, which can be defined as reaching a predefined time limit or number of generations or population convergence, is satisfied.

A. *The problem of diversity loss*

The Genetic Algorithm method operates on a population consisting of individuals who differ from each other by means of a fitness value for individual identification and satisfying pre-defined criteria for selection operation. This portion of differences in population is called diversity [3].

Moreover, a major problem in applying genetic algorithms in real-world problems is how to reduce the large number of evaluations of the objective function. The simplest approach is a search with a small population. However, the diversity of solutions is often lost with this solution strategy, undertaking a complete scan of the search space and causing, in some cases, the premature convergence of the method for minimum (maximum) locations.

III. THE DISCRETE WAVELET TRANSFORM

Due to the different origins of wavelets, their properties and construction can be motivated and understood in different ways. Lifting technique is one of these ways and it has some structural advantages in relation to traditional approaches [2].

The lifting technique is a method introduced by W. Sweldens in 1994 [3], which allows some improvements on the properties of existing wavelet transforms. The basic idea of this technique is to exploit the correlation present in most real life signals to build a sparse approximation. In contrast to traditional approach, which relies heavily on the frequency domain, the lifting scheme derives all constructions in the spatial domain. This feature allows that the lifting algorithms can easily be generalized to higher dimensions and complex geometric structures.

For a simple introduction of the lifting scheme we considered a finite signal of length 2^j, which is represented here as:

$$s^j = \{s_1^j, s_2^j, s_3^j, \ldots, s_{2^j}^j\} \quad (1)$$

The lifting scheme assumes that the numbers $s_i^j, i = 1, \ldots, 2^j$, are not randomly distributed, but contain some correlation between the sample and its neighbors. Then an odd sample s_{2k+1}^j can use the average of its two even neighbors for its prediction. The detail d_k^{j-1} is defined as the difference between the odd sample and its computed prediction [2], as expressed by:

$$d_k^{j-1} = s_{2k+1}^j - (s_{2k}^j + s_{2k+2}^j)/2 \quad (2)$$

Therefore, if the sample and its neighbors have almost the same value, then the difference is of course small, and the prediction is good.

To preserve the average value of the original signal the values of the difference are redistributed to the computed averages issued from the prediction phase. This operation is called update and is defined by (3).

$$s_k^{j-1} = s_{2k}^j + (d_{k-1}^{j-1} + d_k^{j-1})/4. \quad (3)$$

This prediction and update steps are of order two. In this case, the prediction will be exact, if the original signal is linear and the update will preserve the average and the first moment.

IV. THE PROPOSED APPROACH

The Discrete Wavelet Transform (DWT) is applied to the population in each 10 generations, decimating 50% of individuals, trying to maintain the initial diversity. Individual survivors are evaluated and subjected to conventional operations of the GA. Before the application of the DWT the population is clustering using k-means algorithm in order to group neighboring individuals.

The method was applied to unrestricted optimization problems involving test functions with several local minimum. One of those test problems is the *Rastringin* function defined in (4) and presented in Fig. 1.

$$Ras(x, y) = 20 + x^2 + y^2 - 10(\cos 2\pi x + \cos 2\pi y) \quad (4)$$

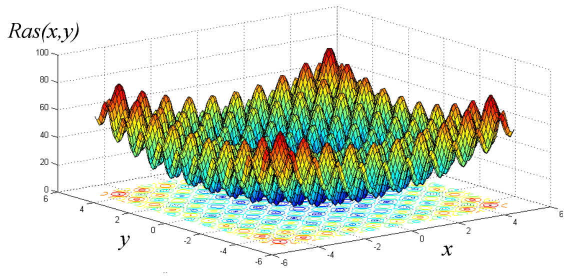

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Fig. 1. Unrestricted optimization test problem

The average number of the objective function evaluations (n) and the efficiency (%) after 20 simulations were analyzed and compared the results of the traditional GA. Efficiency is measured by the rate of convergence in 20 simulations. These results are reported in Table I.

TABLE I
AVERAGE NUMBER OF EVALUATIONS AND EFFICIENCY

	GA	GA+Wavelet
n	4680	4668
%	0.80	0.85

The numerical diversity, evaluated using the moment of inertia measure, are shown in Fig. 2.

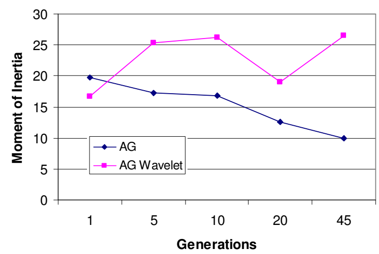

Fig. 2. The population numerical diversity

The results show that the use of wavelet transform in GA, as is being proposed, is feasible for the test case. The proposed approach seems to be effective to maintain the initial population's diversity. The efficiency of the method was at least the same for the test problem. The optimal number of clusters and the interval of dwt applications should be better investigated.

Further tests in real problems should be carried out.

V. REFERENCES

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